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AN APPARATUS FOR THE RAPID VAPORIZATION OF CARBON DISULPHIDE

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INTRODUCTION

One of the alternative requirements of the quarantine No. 62, recently established by the Federal Horticultural Board on the interstate movement of narcissus bulbs, is that any bulbs found infested with either the narcissus bulb fly, *Merodon equestris* Fab., or the lesser bulb fly, *Eumerus strigatus* Fallen, must be fumigated with carbon disulphide at the rate of 25 to 30 pounds per 1,000 cubic feet, under a 27-inch vacuum for a period of one and three-fourths to two hours. Since this ruling requires the use of carbon disulphide under vacuum, and is useful only when the proper equipment is available, it seemed desirable to develop a practical and simple method which growers could use for treating infested bulbs under field or storage conditions, and one which might be used as a substitute. It was thought that by extending the time of exposure, results comparable to those of vacuum fumigation might be obtained.

However, in the course of some preliminary tests under conditions of normal atmospheric pressure, it was found that when carbon disulphide was used, even at as low a rate as 10 pounds per 1,000 cubic feet, at least one-fourth of it failed to vaporize within two hours. In another test a period of seven and one-fourth hours was required to volatilize 9 pounds exposed in a shallow pan outdoors, at a temperature of about 60° F. and a relative humidity of 75 to 90. In vacuum fumigation a similar difficulty is frequently experienced when using heavy dosages, so that a special "gasifyer" has been developed by D. B. Mackie, of the California Department of Agriculture, to hasten the vaporization of the carbon disulphide under vacuum.

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EARLIER EXPERIMENTS

The first apparatus devised to hasten the volatilization of carbon disulphide for fumigation under atmospheric pressure was made by C. F. Doucette, of the United States Bureau of Entomology Field Station at Santa Cruz, Calif., with the assistance of a bulb grower of that vicinity. Developing a suggestion offered by D. B. Mackie, an apparatus was constructed as illustrated in Figure 1, in which an atomizer is used, the container A being placed in the hot-water bath B. This apparatus, for convenience of operation, is attached to the side of a fumigation chamber, a hole for the insertion of the nozzle D being provided in the wall. After filling the outer container with hot water, additional heating may be obtained by adding unslaked lime to the water as needed. In operation, the liquid carbon disulphide is allowed to heat for several minutes in the apparatus and is then sprayed into the fumigation chamber with an air pump E operated by hand. According to the results of preliminary experi-

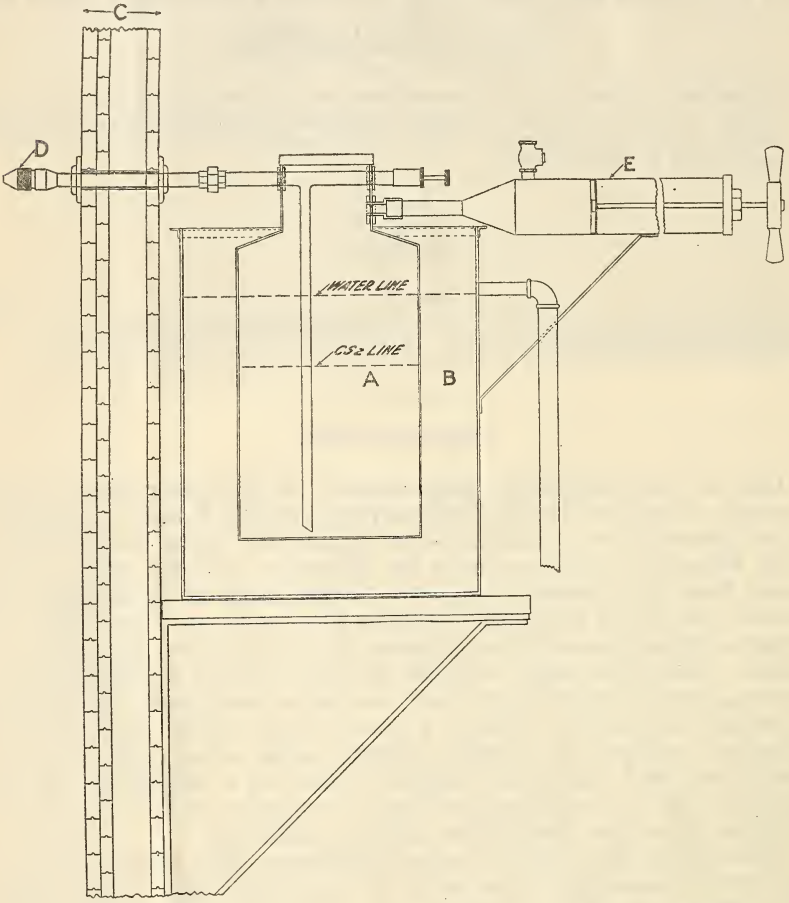

FIG. 1.—Apparatus used by C. F. Doucette for vaporizing carbon disulphide

ments, this method worked satisfactorily, but its usefulness is probably limited to small operations, where the content is 100 cubic feet or less. At this point the writers took up the problem.

An attempt was made to completely gasify the carbon disulphide by heating it in a closed container and then releasing the gas to the atmosphere. To accomplish this the apparatus shown in Figure 2 was used. This consisted of a metal container A of about 2 liters capacity, provided with a ⅜-inch opening at each end. One of the openings was fitted with a stopper C that served as a safety valve, and the other was provided with a valve D and a pressure gauge E. Tests were conducted with this apparatus, using 453-gram and 905-gram charges of carbon disulphide, with the temperatures of the hot-water bath varying between 70° and 75° C. When, after a few minutes, the pressure gauge registered 20 to 30 pounds, the valve was opened and the carbon disulphide released. The carbon disulphide spurted forth only partially vaporized, demonstrating that this is not a satisfactory type of apparatus. The reason for this is that it is impossible to heat the carbon disulphide to a point high enough, because of the great fire hazard.

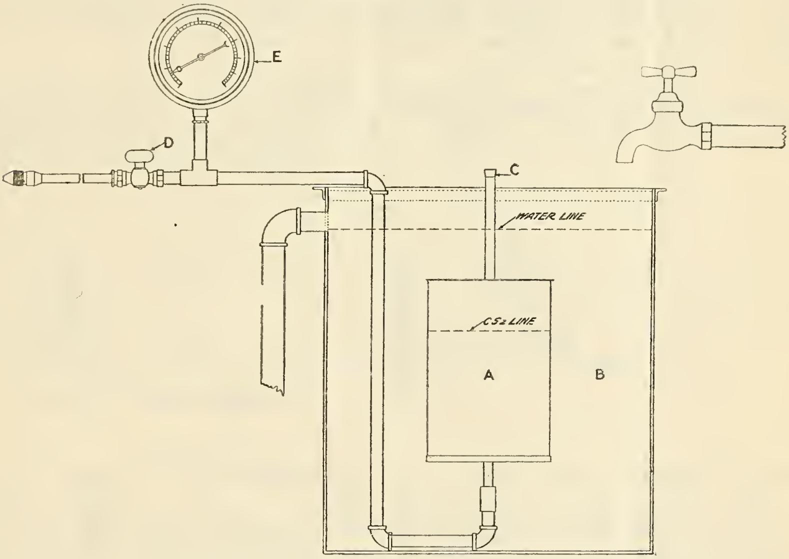

FIG. 2.—Apparatus used for heating carbon disulphide under pressure

The second attempt to vaporize carbon disulphide was made by passing it through coils around which hot water was being circulated. A 12-inch glass coil condenser was used for this purpose, but the method was not satisfactory and the attempt was abandoned, since it was found to be impossible to free the coils quickly enough of the gas formed.

DESCRIPTION OF THE APPARATUS

Finally it was decided to try evaporating the liquid by placing a heated coil in it. The apparatus developed for this purpose consists of a copper coil placed in the bottom of a shallow copper pan with flaring sides. The bottom is made in the form of a flattened cone, so that the carbon disulphide may drain to a low point. The inlet of the coil is connected directly to the hot-water-supply system and provided with a valve to control the flow of water, which enters the outside coil, so that the hottest water is available for the last portions of the carbon disulphide. The outlet has a short hose attached so that the water used can be collected and measured. The inlet and outlet of the coil used in these experiments were each provided with a thermometer so that the temperature at these points could be read. One size of this apparatus is shown in Figure 3, and the constructional details are as follows:

The pan (fig. 3, A) is made of cold-rolled 16-ounce copper. It has a maximum depth of 2⅛ inches and a diameter of 20¾ inches at the top and 15 inches at the bottom. The altitude of the cone B forming the base is three-fourths of an inch. The coil C consists of 15 feet of one-half inch seamless copper tubing, the innermost turn having a diameter of 3¼ inches. The tank or reservoir D is intended for use when a hot-water-supply system is not available, and its installation may be arranged accordingly. The water discharge E may be connected directly to the sewer or other convenient outlet. The size of the apparatus can be varied to suit the needs of any particular condition.

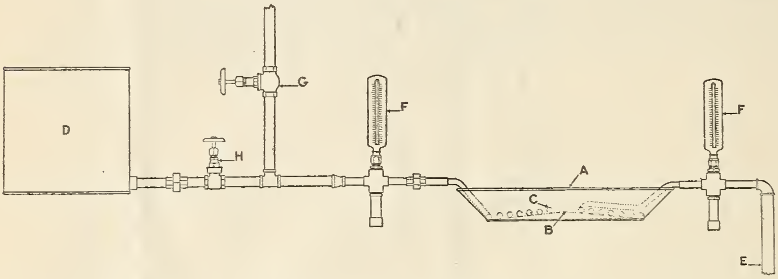

FIG. 3.—Construction details of vaporizer used for experiments shown in Tables 1, 2, and 3

THE APPARATUS IN OPERATION

The apparatus was set up out of doors and used for a series of experiments. The method of operation was as follows: Water having been run through the coil until the desired temperature was reached, the carbon disulphide was quickly poured into the pan and the reading of both thermometers taken. At the same time a receptacle was placed under the water outlet. Temperature readings were taken at about minute intervals with thermometers graduated to 0.2° C., and at the close of the experiment the water collected was measured. The difference was taken between the average inlet and outlet temperatures and the "calories used" calculated to see whether the apparatus was working efficiently. The other data of the experiments are given in Table 1.

TABLE 1.—*Vaporization of carbon disulphide with three-eighths-inch coil*

Experiment No.	Weight of carbon disulphide	Average temperature		Temperature difference	Water volume used	Calories used	Time required		Grams carbon disulphide per second	Grams carbon[1] disulphide per calorie
		Inlet	Outlet							
	Grams	° *C.*	° *C.*	° *C.*	*C. c.*		*Min.*	*Sec.*		
1	453	73.2	53.3	19.9	2,300	45,500	2	30	3.02	0.0099
2	905	74.2	46.9	27.3	3,680	100,500	4	30	3.35	.0090
3	905	66.6	45.7	20.9	4,250	89,000	6	00	2.51	.0102
4	905	75.0	46.6	28.4	2,830	80,500	4	45	3.17	.0112
5	2,265	79.5	45.3	34.2	6,250	214,000	9	30	3.97	.0106
6	2,265	79.9	44.9	35.0	6,400	224,000	6	40	5.66	.0101
7	2,265	79.7	45.1	34.6	5,680	196,500	7	50	4.82	.0115
8	2,265	73.6	50.6	23.0	8,385	193,000	4	30	8.39	.0117
9	2,265	65.6	49.1	16.5	11,000	181,500	5	00	7.55	.0125
10	2,265	65.6	50.8	14.8	12,700	188,000	2	40	14.16	.0120
11	2,265	72.3	50.5	21.8	8,400	183,000	3	00	12.58	.0124

[1] The heat of vaporization of carbon disulphide is 85 calories per gram. The theoretical value is therefore 0.0118. The heat required to raise the temperature of the carbon disulphide to its boiling point has not been taken into consideration.

In the preceding experiments the diameter of the pipe in the heating coil was three-eighths of an inch and the surface was 1.87 square feet. Observing that it was impossible to boil the carbon disulphide over the whole surface of the coil, because the water did not flow fast enough, a second one was built of one-half-inch pipe, having 2 square feet of surface. This apparatus was equipped with thermometers (fig. 3, F) graduated to 2° C., and used for the experiments shown in Table 2, which were performed in a greenhouse.

TABLE 2.—*Vaporization of carbon disulphide with one-half-inch coil*

Experiment No.	Weight of carbon disulphide	Average temperature		Temperature difference	Water volume used	Calories used	Time required		Grams carbon disulphide per second	Grams carbon[1] disulphide per calorie
		Inlet	Outlet							
	Grams	° *C.*	° *C.*	° *C.*	*C. c.*		*Min.*	*Sec.*		
1	4,077	56.7	51.2	5.5	60,250	331,500	8	40	7.84	0.0123
2	4,077	56.8	49.0	7.8	40,450	315,500	10	20	6.58	.0129
3	4,077	76.7	58.7	18.0	16,500	297,000	1	50	37.06	.0137
4	4,077	58.7	52.0	6.7	54,100	363,500	9	00	7.55	.0112
5	4,077	84.4	59.4	25.0	12,650	316,000	1	55	35.45	.0129

[1] See footnote under Table 1.

A third set of experiments was made to determine the suitability of the apparatus for a grower without running hot water at his disposal. The pipe was disconnected and a small tank, to serve as a reservoir for hot water, was substituted. By heating water in pails and filling the reservoir, field conditions under which such an apparatus might be used were simulated. In each experiment from 5 to 10 liters of hot water was run through the coils to warm up the pipes before the test was begun. With this apparatus the experiments in Table 3 were carried out.

TABLE 3.—*Vaporization of carbon disulphide with one-half-inch coil and hot-water reservoir*

Experiment No.	Weight of carbon disulphide	Average temperature		Temperature difference	Water volume used	Calories used	Time required	Grams carbon disulphide per second	Grams carbon[1] disulphide per calorie
		Inlet	Outlet						
	Grams	° *C.*	° *C.*	° *C.*	*C. c.*		*Min. Sec.*		
1	4,077	72.4	52.4	20.2	14,850	300,000	6 00	11.33	0.0136
2	4,077	74.4	52.2	22.2	13,700	304,000	5 35	12.17	.0134
3	4,077	79.8	56.3	23.5	13,300	312,500	5 00	13.59	.0130

[1] See footnote under Table 1.

DISCUSSION AND RECOMMENDATIONS

Because of the great fire hazard of carbon disulphide, the question of danger was carefully considered. The lowest temperature reported for the ignition of carbon disulphide in contact with copper is 96° C. It was decided to allow a margin of 12° and not use water above 84° C. for heating the coils. As would be expected, the higher the temperature. the more rapid the rate of vaporization. In the experiments recorded in Table 1 the small pipe, together with the obstructions due to the insertion of thermometer wells in the system. kept the rate of flow of water so low that it was usually impossible to keep the "outlet" temperature much above the boiling point of carbon disulphide.

With the second coil, although the superficial area was approximately the same, the greater flow of water obtained with the one-half-inch pipe greatly increased the outlet temperature and therefore the rate of vaporization. With an initial temperature of 76.7° C. (Table 2, experiment No. 3) the rate of vaporization was 37.06 grams per second, or about three times as great as the results obtained with the three-eighths-inch coil (Table 1, experiment No. 11).

The practical application of this apparatus is shown more conclusively by the results given in Table 3. The small quantity of hot water required to vaporize 9 pounds of carbon disulphide (which may be considered a normal quantity for fumigation purposes) could easily be provided by any grower wishing to use this method with the ordinary household equipment. If no more hot water than the amount recommended is used. it should be at the point of boiling.

Where a hot-water system is available. a permanent installation can be made by connecting the apparatus directly with it. The rapidity of the vaporization is so great that a much larger quantity of carbon disulphide can be handled in a reasonable length of time. Moreover, the apparatus is as safe as is possible with such hazardous material. If much larger quantities of carbon disulphide were to be used. a coil with a larger pipe would probably be advisable. in order to cut down the time as much as possible. In order to assist in the selection of the proper sized vaporizer for any particular condition. the information given in Table 4 has been prepared.

TABLE 4.—*Coil surface and length of copper tubing required for vaporizing varying quantities of carbon disulphide*

Pounds of carbon disulphide	Square feet of coil surface	Length of seamless copper tubing required			
		⅜-inch	½-inch	⅝-inch	¾-inch
		Feet	*Feet*	*Feet*	*Feet*
1 to 10	2	20	15	12	----------
11 to 20	3	31	23	18	----------
21 to 30	4	----------	31	24	20
31 to 40	5	----------	----------	31	25
41 to 50	6	----------	----------	37	31

The information in Table 4 is only tentative, being deduced from the data in the preceding tables and not based on experimental evidence. In any case, for each 10 pounds of carbon disulphide, 4 gallons of water should be run through the coil, having an initial tem-

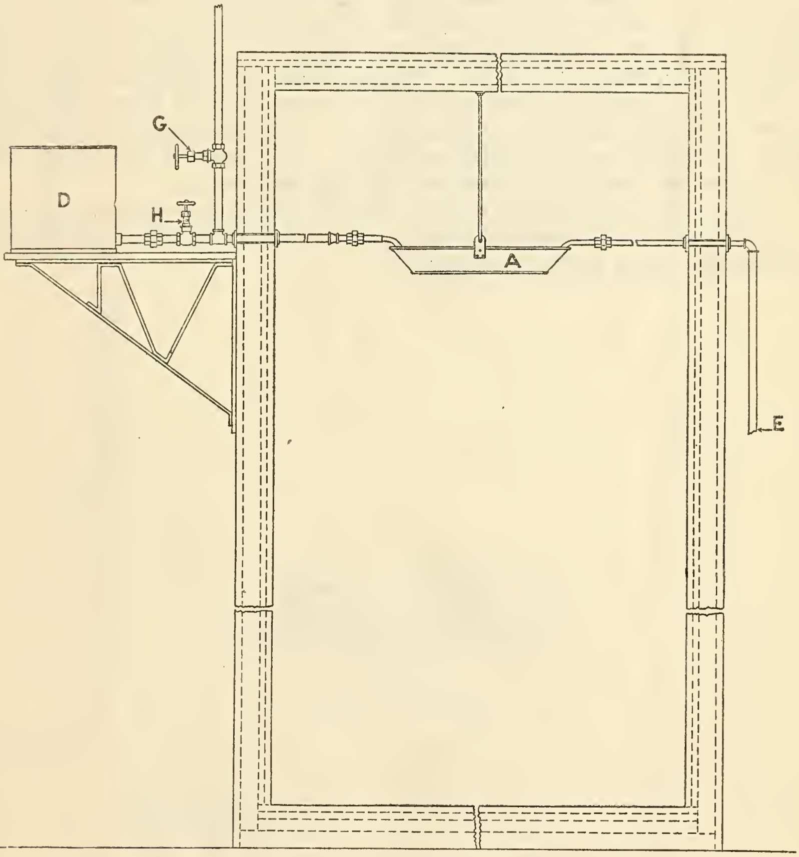

FIG. 4.—Apparatus as recommended to be installed in fumigation chamber. The carbon disulphide in the pan A is heated by water drawn from a hot-water system through a valve G, or from a reservoir D through a valve H

perature of not less than 75° C. and an outlet temperature of not more than 50° C.

The values in Table 4 are determined on the basis of transmitting 0.023 calorie per square centimeter per second per degree difference. This rate of evaporation, however, is applicable to only one set of conditions—namely, when the inlet temperature of the water is between 72° and 80° C., the time interval from five to six minutes, and when there is a uniform flow of water of approximately 4 liters per minute. For practical purposes, however, the rate of evaporation varies directly as the area of the coil surface, provided sufficient hot water is run through to heat the whole coil. If, therefore, it is desired to evaporate a given dosage in half the length of time indicated in the table, it is necessary to double the coil surface. From these relationships, therefore, it is rather easy to select a satisfactory coil. It is also well to point out that since there are so many variable factors to be taken into consideration in the design of an evaporator, and since a change in any one factor varies the rate of evaporation greatly, almost any size of coil will serve the purpose if the other factors are properly varied. The materials necessary are easily obtainable at almost any hardware store. Considerable leeway in diameters of copper tubing is given in order that the prospective builder may utilize the copper tubing available. The volume of the pan can, of course, be changed to meet any dosage required.

A plan for a satisfactory method of installing a vaporizer, with or without a hot-water-supply system, in a fumigation chamber has been prepared and is shown in Figure 4.

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